TREE OF HEAVEN CONTROL PROJECT

at

FRIENDSHIP HILL NATIONAL HISTORIC SITE

2007-2009

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ABSTRACT

In the Winter of 2007, USDA Forest Service personnel and USDI Park Service personnel established a tree of heaven (*Ailanthus altissima*) control project at Friendship Hill National Historic Site. The purposes of this project were to eradicate this species from the mid-story and overstory, prevent spread into uninfested areas and to eliminate any tree of heaven before it reaches sexual maturity.

One round of mechanical treatment and two rounds of chemical treatments were implemented every year from 2007 to 2009. A total of 53,976 tree of heaven was treated over this three year period with treatment of 21,017 in 2007, 26, 897 in 2008 and 6062 in 2009. Approximately 95.9 percent (51,753 of the 53,976) of the total tree of heaven treated were seedlings. Approximately 36.2 percent of the seedlings were mechanically treated and the remaining 63.8 percent were chemically treated.

After a moderate increase in the number of tree of heaven in 2008, a very significant decrease was experienced in 2009. This project should continue in the future but at much less intensity. In 2010, the tree of heaven control project should be limited to one round of herbicide treatments.

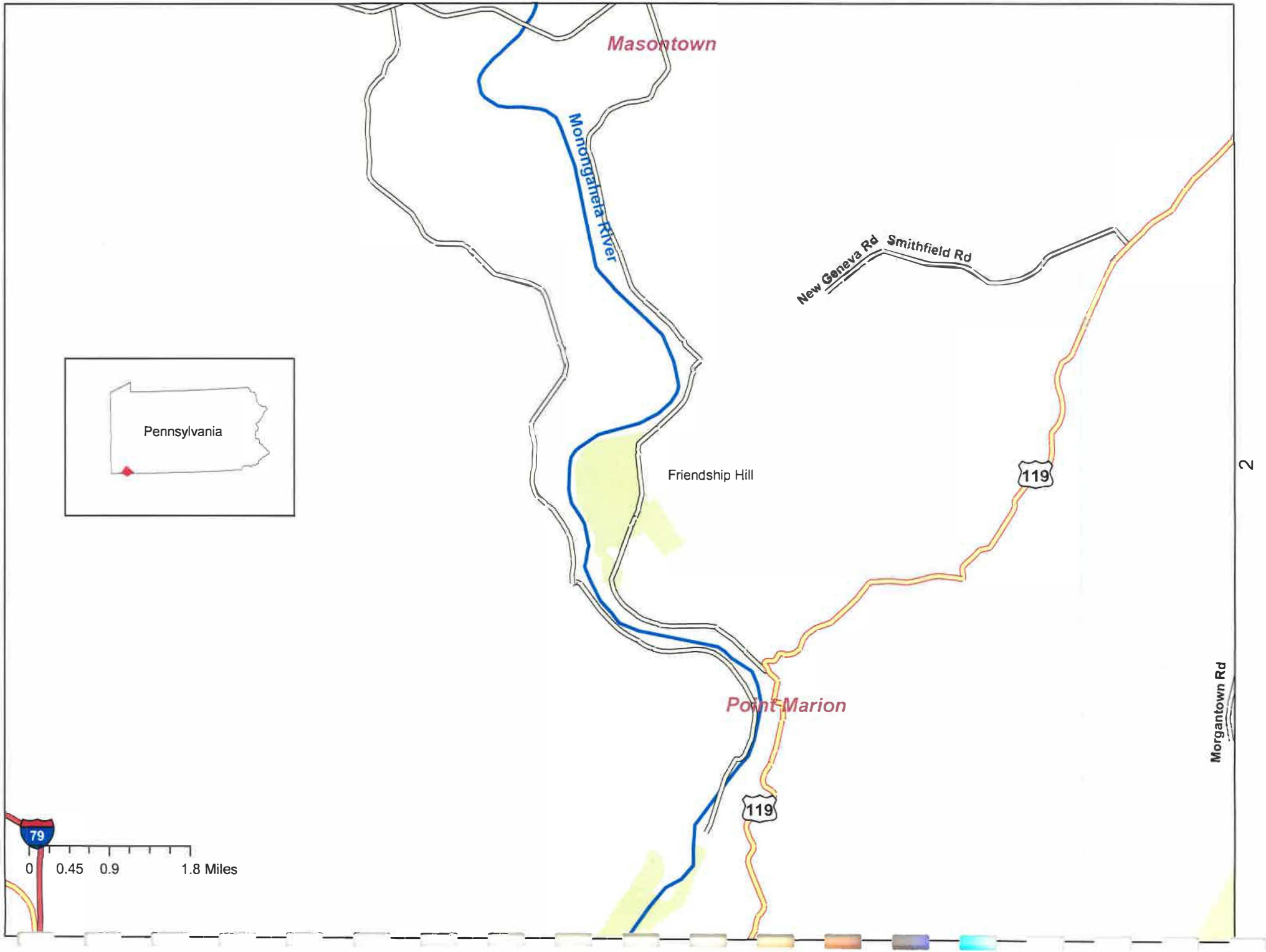
INTRODUCTION

Friendship Hill National Historic Site (FRHI) is a 677 acre National Park Service site located on the banks of the Monongahela River approximately 3 miles north of Pt. Marion, PA (Figure 1). FRHI was established in 1978 and is the former estate of Albert Gallatin, who served as the Secretary of the Treasury under Thomas Jefferson and James Madison. In addition to Gallatin's 35 room mansion, FRHI is comprised by some maintenance buildings, roads, an extensive trail system, agricultural fields, abandoned fields, four small streams, railroad tracks and forested areas. Most of the terrain is fairly flat to gently sloping, except the very steep slopes that face the Monongahela River.

Tree of heaven was introduced into the United States from China in 1784 as a garden species and then was used as a pollution tolerant urban tree in Philadelphia. It was available at tree nurseries by 1840. Tree of heaven has smooth light gray bark with thick branches that have pinnately compound leaves up to 3 feet in length with 11-41 leaflets per leaf. Tree of heaven is often found in disturbed habitats, along roadsides, fence rows, abandoned fields, forest edges, forest openings and urban areas. It often grows in dense stands that displace native plants and may grow up to 6 ½ feet in a growing season. Reproduction is by seed and vegetatively via root suckering. Tree of heaven is dioecious, as plants are either male or female. Females may produce as many as 300,000 seeds per year. Seeds are produced in a 180° two-winged samara which may remain on the tree throughout the entire winter. Crushed tree of heaven leaves and stems give off a rancid peanut butter smell. Unlike most invasive plant species which foliate before most native plants, tree of heaven is one of the last plant species to foliate in the Spring. Another oddity of tree of heaven compared to other invasive plants is the length of time the seeds remain viable in the seedbank. Most invasive species produce seeds that stay viable several years up to two or three decades while tree of heaven seeds remain viable for only a year or two.

Although tree of heaven is not the most widely distributed invasive plant species at FRHI, it was selected because it is not only found in the understory but also in mid-story and the overstory. Another reason tree of heaven was selected is that it has the ability to rapidly colonize areas and poses a significant threat when established. An inventory conducted by the Western

Figure 1. -- General location map of Friendship Hill National Historic Site



Pennsylvania Conservancy at FRHI in 2005 revealed that tree of heaven exceeded 20% cover in half of the areas where it was found and in some areas it is a substantial part of the canopy. It was recommended in this inventory report that tree of heaven should be a target of control and that eradication may be possible, with a diligent effort, in some areas.

METHODS

Using an aerial photograph and a topographic map, 415 acres were delineated where tree of heaven was likely to occur (forest edges, abandoned fields, forest openings and disturbed areas). Transects were then walked through 384 acres in 2007 and an additional 31 acres in 2008 and 2009 (Figure 2). When tree of heaven was found, a plot was established and marked on a map. Directions to each plot were recorded. The plots varied in size, shape and number of tree of heaven based on its distribution and the geographic features of an area. Each plot was then designated with a number or a letter. For the most part, a plot was numbered if it had a tree of heaven large enough to have a number painted on it. Conversely a plot that had all small trees received a letter. The tree of heaven in each plot was then marked with paint primarily to keep track of them while tallying during the initial survey. The number of seedlings (dbh ≤1″) was recorded for each plot as well as the number of stems in each 2″ dbh size class. Seedlings comprised the vast majority of the tallied tree of heaven.

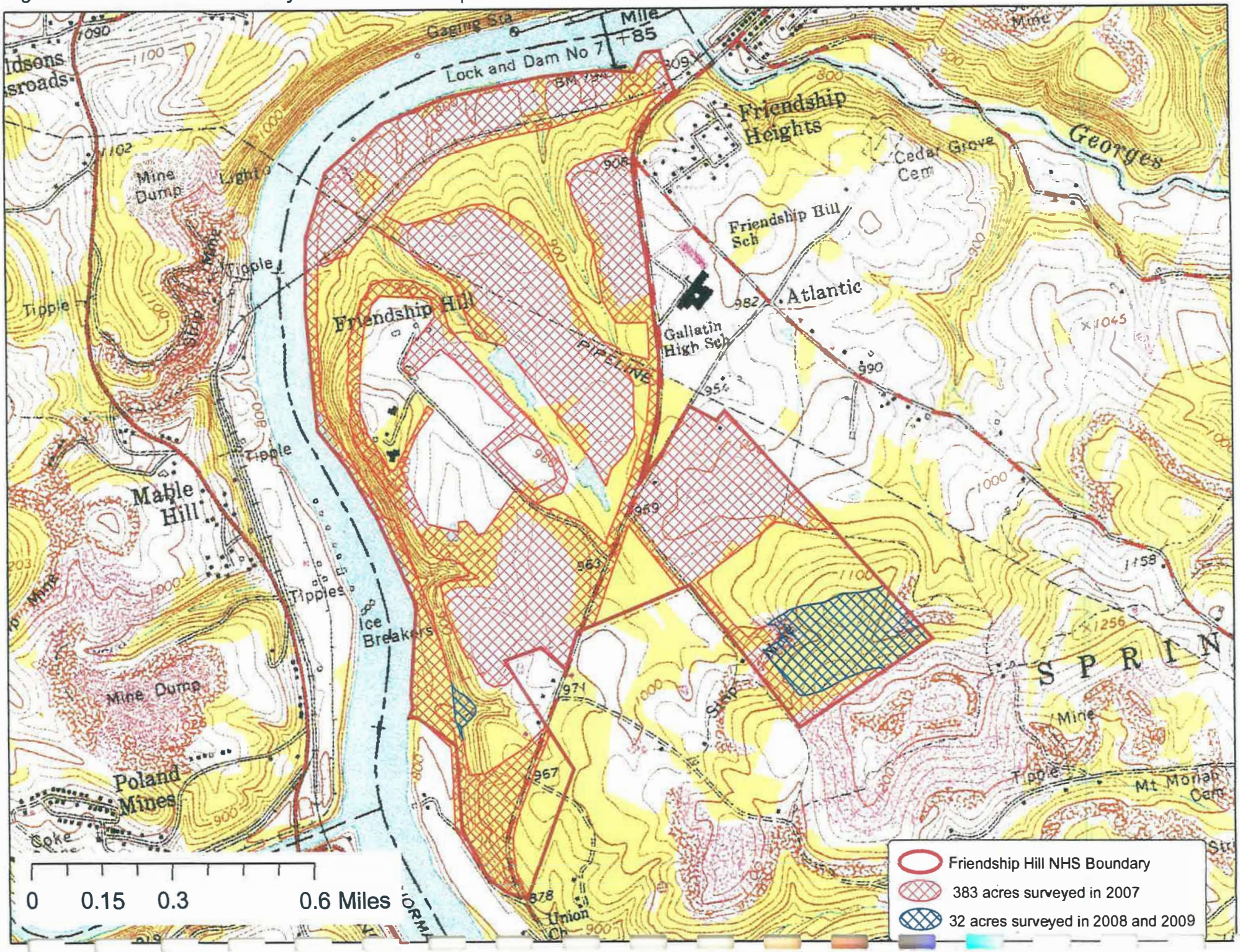
In order to reduce the amount of herbicide used, a round of mechanical treatment (hand pulling) was implemented annually. In late Winter/early Spring, as many of the seedlings as possible were pulled in each plot. A seedling was not counted as being pulled unless all or a vast majority of its root system was also pulled. This helped prevent double counting seedlings as being pulled and then later as being herbicided.

Two rounds of herbicide treatments were conducted annually at each plot. The first round was conducted during the last week of May and the first week of June with the second round during late July through August. Garlon 3A® (44% triclopr triethylamine salt) and Razor Pro® (41% glyphosate) were used during this process. A foliar application of Razor Pro was made to all tree of heaven seedlings less than 7 feet tall using a low pressure back pack sprayer and or hand held garden type sprayer. The Razor Pro was in a solution at 7.5% mixed with water at 92.5% and was applied to thoroughly cover the tree of heaven foliage. The Garlon 3A was applied undiluted using the "hack and squirt" technique to all tree of heaven in the 2″ DBH class and greater and seedlings taller than 7 feet. Shallow, downward cuts were made using a hatchet around the stem of each tree of heaven, spaced to allow approximately ½ inch of intact bark between each cut. Using a one quart spray bottle, each cut was treated with Garlon 3A. The amount of herbicide used for each tree during the "hack and squirt" operation was based on the DBH of the tree. Since the larger trees have much larger root systems, more herbicide is needed to kill them. The application rate of the Garlon 3A for each size class follows in the table below.

Application rate of Garlon 3A by DBH size class

DBH	Garlon 3A	DBH	Garlon 3A
Seedlings (≤1″)	5ml	12″	18 ml
2″	1 ml	14″	21 ml
4″	4 ml	16″	32 ml
6″	6 ml	18″	35 ml
8″	8 ml	20″	40 ml
10″	15 ml	22″	44 ml

Figure 2. -- Tree of heaven suvey areas at Friendship Hill National Historic Site.



RESULTS

During the initial survey to locate tree of heaven in 2007, 65 plots (#s 1-54 and letters A-K) were established. Five additional plots (#s 95-99) were established that year during the first round of herbicide treatments while three additional plots (#s 92-94) were established during the second round of herbicide treatments. In 2008, ten more plots (#s 83-91 and L) were established during the mechanical treatment round, three more plots (#s 81-82 and M) were established during the first round of herbicide treatments while an additional plot (#80) was established during the second round of herbicide treatments. In 2009, three plots (#s 77-79) were established during the round of mechanical treatment and one plot (# 76) was established during the first round of herbicide treatments. There were 73 plots established by the end of 2007, 87 by the end of 2008 and 91 by the end of 2009. The plot locations are shown in Figure 3.

There was a total of 21,017 tree of heaven treated in the 73 plots in 2007. Seedlings comprised approximately 92 percent (19,347 out of 21,017) of the total. Mechanical removal totaled 9183 seedlings, 9498 seedlings received a foliar application of the Razor Pro solution and 666 seedlings received a hack and squirt application of Garlon 3A. The number of tree of heaven treated in 2007 is presented by size class in the table below.

Number of tree of heaven (TOH) treated in 2007 by size class

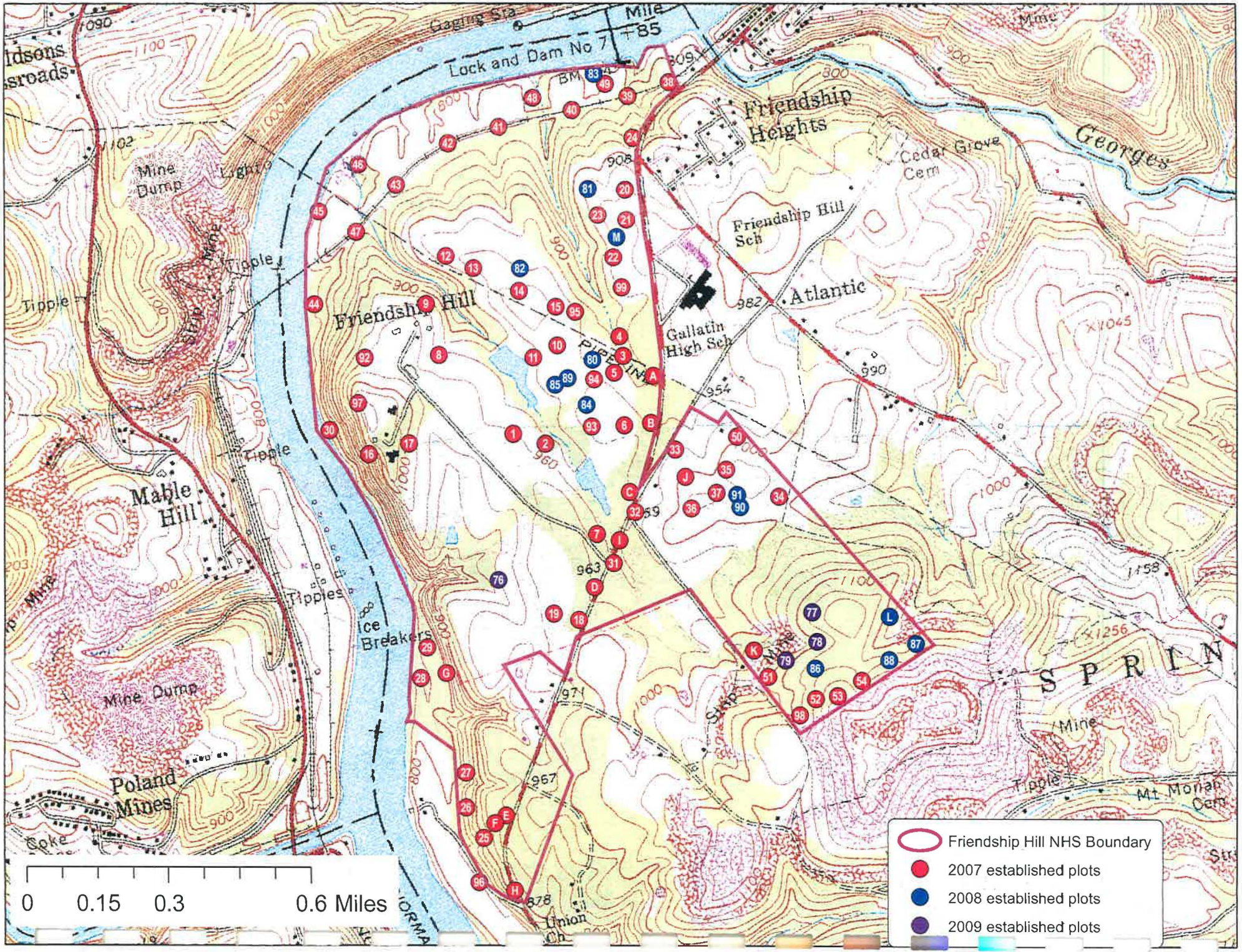
DBH	≤1″(seedlings)	2″	4″	6″	8″	10″	12″	14″	≥ 16″	All size classes
# TOH treated	19,347	661	368	209	203	94	44	39	52	21,017

Similar to the size of the plots, there was a great deal of variation in the number of tree of heaven between individual plots. Individual plot data is presented in Table 1 by size class for all 73 plots. Five of the plots had only a single tree of heaven while five of the plots had at least 1000. For the most part, plots established after the original 65 plots are smaller and have fewer tree of heaven. An exception is plot number 96 where 488 were treated in 2007.

This plot is actually located on private property on the industrial site immediately south of FRHI. This area of tree of heaven had already been detected during the initial survey. Since most of the tree of heaven in the plot were located less than 50 feet from the Park Service boundary, it was decided to treat them (with permission from the industrial site) to eliminate a potential seed source. Permission was granted so the plot was established and treatment was conducted.

In 2008, there was a total of 26,897 tree of heaven treated in the 87 plots. Seedlings comprised 98.3 percent (26,445 out of 26,897) of the total. Mechanical removal totaled 7574 seedlings, 18,511 seedlings received a foliar application of the Razor Pro solution and 360 seedlings received a hack and squirt application of Garlon 3A. Tree of heaven totaled 25,386 in the 73 plots that were established in 2007 and totaled 1511 in the 14 plots established in 2008. The number of tree of heaven treated by size class in 2008 is presented in the following table.

Figure 3. -- Location of the tree of heaven survey plots at Friendship Hill National Historic Site.



Number of TOH treated by size class in 2008.

DBH	≤ 1″ seedlings	2″	4″	6″	8″	10″	12″	14″	≥ 16″	All size classes
# TOH treated in 2007 established plots	25131	126	50	29	18	19	6	5	2	25,386
#TOH treated in 2008 established plots	1314	83	44	24	10	17	6	5	8	1511
Total # TOH treated	26445	209	94	53	28	36	12	10	10	26,897

The total number of tree of heaven increased approximately 30 percent from 21,017 in 2007 to 26,897 in 2008. Looking at the seedling totals, there was an approximately 36.7 percent increase from 2007 to 2008 (19,347 to 26,445). Looking only at the 73 plots established in 2007, there was a 23 percent increase in seedlings from 2007 to 2008 (19,347 to 25,131). The other 255 trees in these 73 plots that were treated in 2008 had a DBH of 2″inches and larger were obviously missed in 2007.

Individual plot data is presented in Table 1 for the 73 plots established in 2007 and Table 2 for the 14 plots established in 2008. Comparing individual plot data from 2007 and 2008 in Table 1, 38 plots showed an increase in the number of tree of heaven while 35 plots showed a decrease. No tree of heaven were detected /treated in 4 of these plots. Looking at the individual plot data in Table 2, 8 of the 14 plots had 50 or less tree of heaven.

Besides the 26,897 tree of heaven treated in 2008, an additional 202 trees were treated that had been previously treated in 2007. All of these trees had been treated with Garlon 3A and showed branch dieback that ranged from 90 to 99 percent prior to re-treatment in 2008. The re-treated trees were tallied but were not included in the total tree of heaven treated for the year or in individual plot data since they had been previously counted the preceding year. The number of re-treated tree of heaven in 2008 is presented by size in the table below.

Number of TOH re-treated with Garlon 3A in 2008 by size class

DBH	≤ 1″ (seedlings)	2″	4″	6″	8″	10″	12″	14″	≥ 16″	All size classes
#TOH re-treated	0	24	47	41	36	9	10	19	16	202

In 2009, there was a total of 6062 tree of heaven treated in the 91 plots. Seedlings comprised 98.3 percent (5961 of the 6062) of the total. Mechanical removal totaled 1994 seedlings, 3910 seedlings received a foliar application of the Razor Pro solution and 57 seedlings received a hack and squirt application of Garlon 3A. Tree of heaven totaled 4445 in the 73 plots established in 2007, 1412 in the 14 plots established in 2008 and 205 in the 4 plots established in 2009. The number of tree of heaven treated by size class in 2009 is presented in the following table.

Number of TOH treated by size class in 2009

DBH	≤ 1″ (seedlings)	2″	4″	6″	8″	10″	12″	14″	≥ 16″	All size classes
# TOH treated in 2007 established plots	4372	46	11	3	7	0	1	4	1	4445
# TOH treated in 2008 established plots	1404	1	1	1	2	2	0	1	0	1412
# TOH treated in 2009 established plots	185	6	4	3	3	1	2	1	0	205
Total # TOH treated	5961	53	16	7	12	3	3	6	1	6062

The number of tree of heaven has decreased approximately 77.5 percent from the 2008 total of 26,897 to the 2009 total of 6062. Seedlings totals have been reduced by approximately 77.5 percent (26,445 to 5961) over the same time frame. Looking at the 73 plots established in 2007, the number of seedlings have decreased approximately 82.6 percent from the 2008 level of 25,731 to the 2009 level of 4372. Looking at the 14 plots established in 2008, the number of seedlings has increased approximately 6.8 percent from the 2008 level of 1314 to the 2009 level of 1404.

Individual plot data is presented in Table 1 for the plots established in 2007, Table 2 for the plots established in 2008 and Table 3 for the plots established in 2009. Comparing individual plot data from 2008 and 2009 in Table 1, tree of heaven numbers have increased in only one plot. There were 15 plots where no tree of heaven were detected/treated in 2009. In plots C, I and J, none have been detected/treated in either 2008 or 2009. Comparing individual plot data from 2008 and 2009 in Table 2 (plots established in 2008), the number of tree of heaven increased in 3 plots, decreased in 10 plots and stayed the same in the other plot. No tree of heaven was detected/treated in one plot in 2009. Looking at individual plot data in Table 3, (plots established in 2009) 3 out of the 4 plots had less than 30 tree of heaven. The total number of treated tree of heaven at each plot is presented in Figure 4 for 2007, Figure 5 for 2008 and Figure 6 for 2009.

As previously mentioned, there were 16 plots where no tree of heaven were detected/treated in 2009. Fifteen of the plots were established in 2007 while one was established in 2008. All 16 of the plots had a total treatment number of 50 or less during the year they were established. Fifteen plots had a total treatment number of 501 or greater in 2007 while in 2009, no plots had a total treatment number of 501 or greater.

Besides the 6062 tree of heaven that were treated in 2009, an additional 26 trees were re-treated and were not included in the total number of tree of heaven treated or in the individual plot data. Listed in the table below are the number of tree of heaven re-treated in 2009 by size class and year of plot establishment.

Number of TOH re-treated with Garlon 3A in 2009 by size class and plot established year.

DBH	≤ 1″ (seedlings)	2″	4″	6″	8″	10″	12″	14″	≥ 16″	All size classes
# TOH re-treated in 2007 established plots	0	0	4	3	8	3	3	2	1	24
# TOH re-treated in 2008 established plots	0	0	0	0	0	0	0	0	2	2
Total # TOH re-treated	0	0	4	3	8	3	3	2	3	26

Figure 4. -- Number of treated tree of heaven by plot at FRHI in 2007.

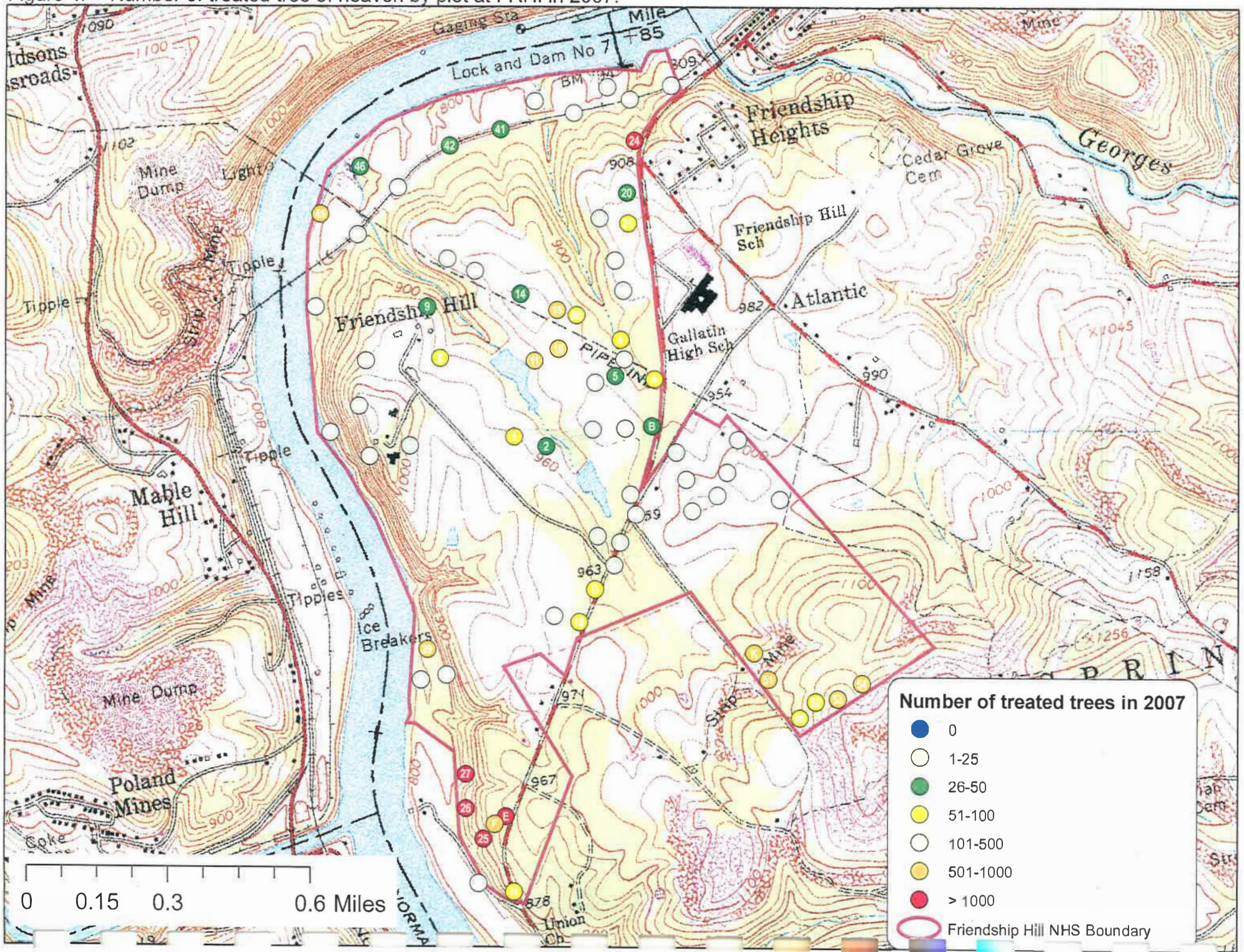


Figure 5. -- Number of treated tree of heaven by plot at FRHI in 2008.

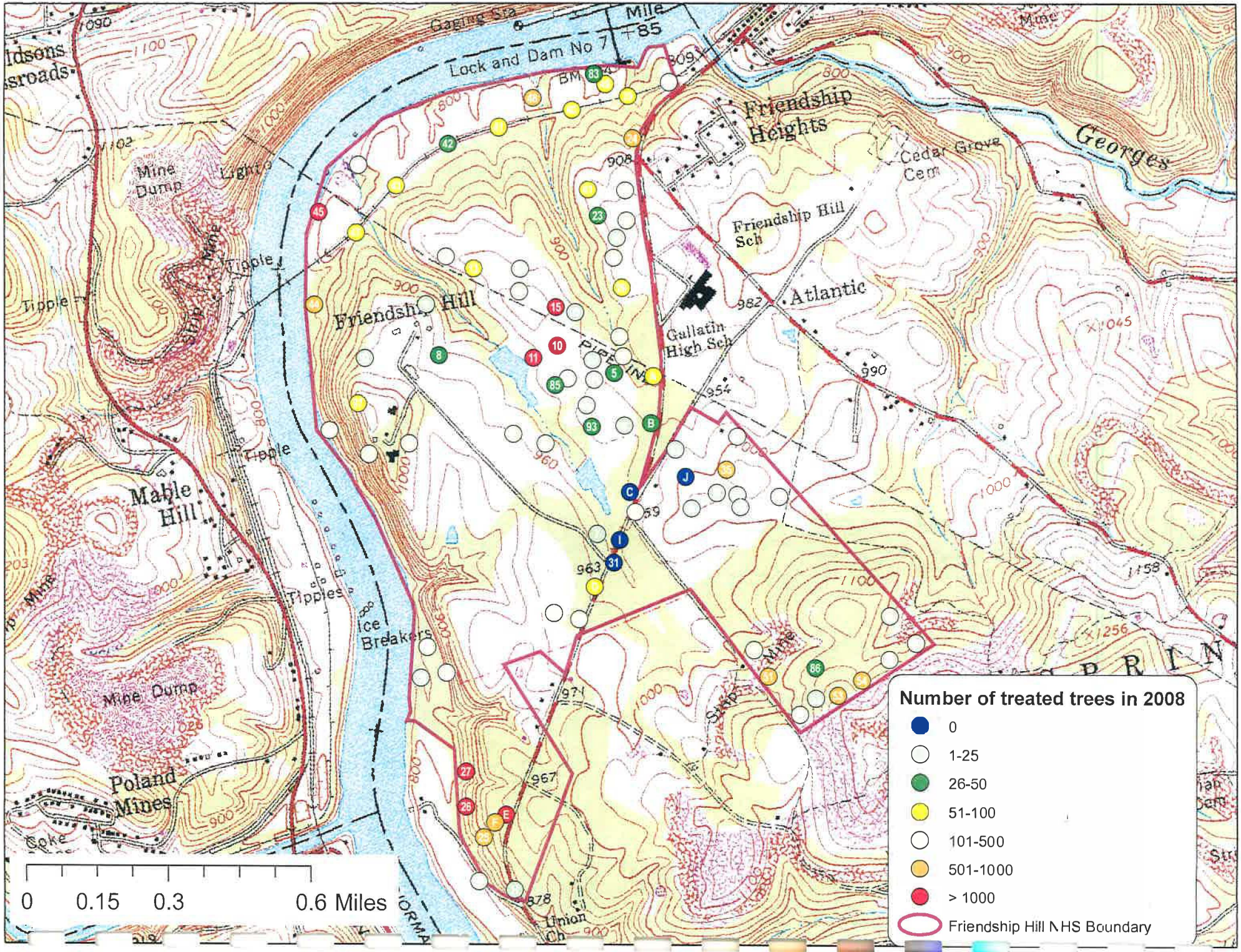
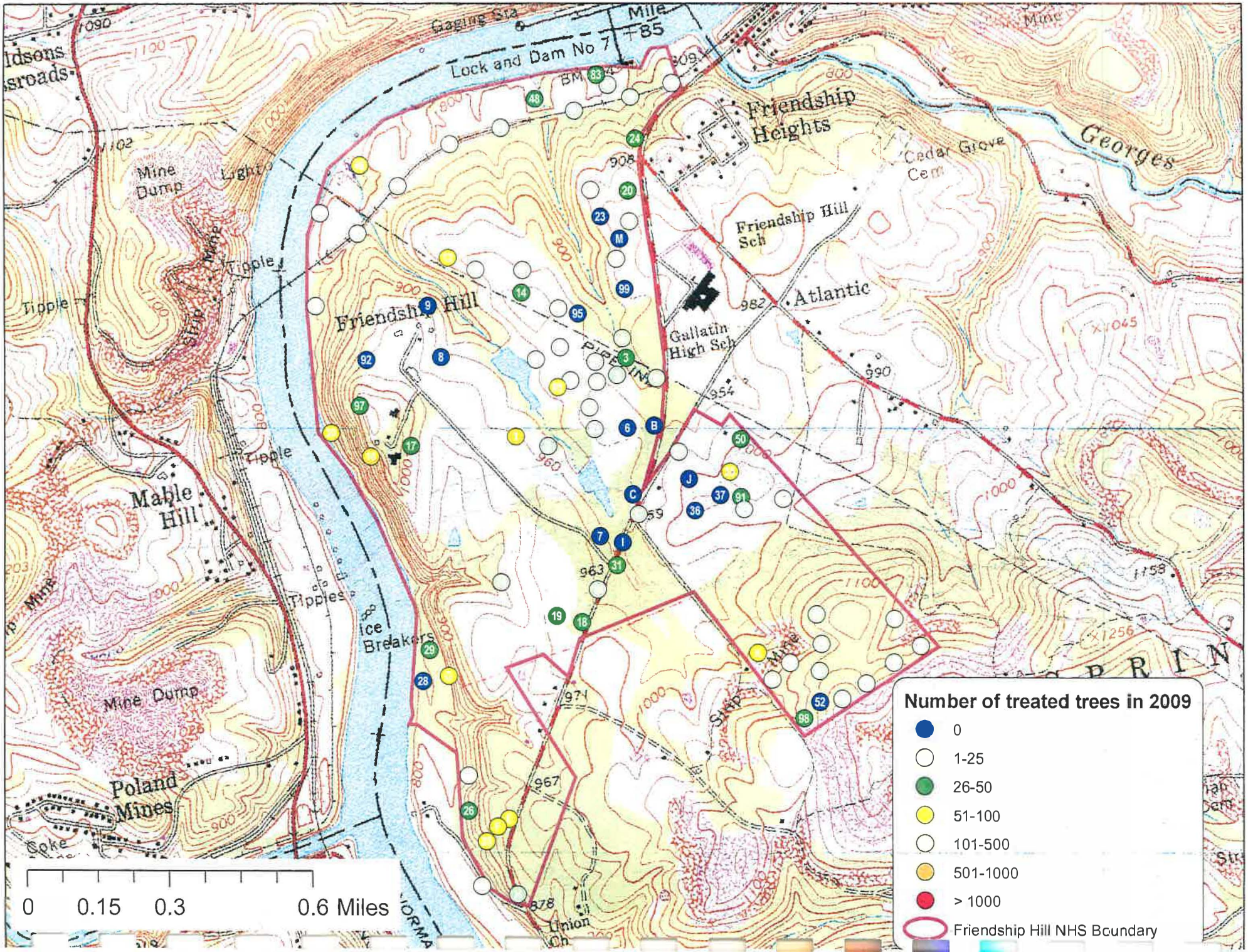


Figure 6. -- Number of treated tree of heaven by plot at FRHI in 2009.



Forest Service personnel have spent approximately 676 hours conducting field work for the tree of heaven control project at FRHI. The initial survey to find tree of heaven and the establishment of the original 65 plots took approximately 76 hours. It took an additional 229 hours of field work to complete all three rounds of treatment in 2007, 268 hours in 2008 and 103 in 2009. These treatment hours also include the time it took to establish the plots added after the initial plot establishment. However, the time it took to establish these additional plots was fairly minimal (less than 10 hours). Not surprising that the time spent conducting treatments is closely related to the amount of tree of heaven treated. There was a 30 percent increase in the amount of tree of heaven treated from 2007 to 2008 and a 69.7 percent decrease from 2008 to 2009. The time it took to treat tree of heaven showed a 17 percent increase in 2008 and a 61.6 percent decrease in 2009.

Approximately 456 ounces (3.6 gallons) of Garlon 3A and 700 ounces (5.5 gallons) of Razor Pro have been used for this project. Herbicide usage has decreased for both herbicides every year. Approximately 310 ounces of Garlon 3A was used in 2007, 106 ounces in 2008 and 40 ounces in 2009. Razor Pro usage was 320 ounces in 2007, 240 ounces in 2008 and 140 ounces in 2009. It was interesting to see that the amount of Razor Pro used in 2008 was 25 percent less than used in 2007 although approximately 95 percent more seedlings were treated with Razor Pro in 2008 than in 2007. This was probably caused by the fact that most of the seedlings treated in 2008 were smaller and they required less herbicide than those treated in 2007. It is likely that the majority of seedlings treated in 2008 germinated in 2007 or 2008.

DISCUSSION

Similar to most invasive species, a site infested with tree of heaven cannot be controlled with a single treatment or even multiple treatments in a single year. Treatment one year may actually lead to an increase in the number of tree of heaven seedlings the following year. Removal of overstory and mid-story tree of heaven will allow an increase in the amount of sunlight reaching the forest floor and will stimulate the germination of tree of heaven seed stored in the left litter and duff. The data from this control project shows that seedling numbers will increase the first year after the initial treatment. Fortunately, tree of heaven seeds remain viable for only a year or two. With the removal of most of the seed producing (sexual mature female) trees in 2007 and additional ones in 2008 and 2009, the amount of viable seed left in the leaf litter and duff at FRHI has been greatly depleted. It is expected that tree of heaven seedling numbers will be significantly reduced again in 2010.

Tree of heaven will be virtually impossible to eradicate entirely at FRHI given the large amount of tree of heaven located within close proximity which serves as a seed source. Complete eradication from FRHI would have been an unrealistic goal of this project. One of our goals was to eradicate all the sexual mature tree of heaven at FRHI. Sexual mature trees are females large enough to produce seed and/or root suckers and male trees large enough to produce root suckers. Reproduction starts early in tree of heaven as seeds have been seen of female trees as small as 4" DHB. Assuming this is the size of tree when reproduction starts, it is estimated that there has been a 95-99 percent reduction in these trees. The number of treated 4" DBH trees and larger has decreased from 1009 in 2007 to 243 in 2008 to only 48 in 2009. The number of new plots added has also decreased from 14 in 2008 to 4 in 2009. Very few sexually mature trees now exist in the current plots and there are very few, if any, undetected patches of tree of heaven at FRHI. The vast majority of the viable tree of heaven seed that exists now and in the near future will come from trees not located at FRHI.

As previously mentioned, a mechanical treatment round was conducted annually at FRHI for several reasons. The major reason it was implemented was to reduce the amount of herbicide used on the project and thus reduce the potential of non-target impacts on adjacent vegetation. Approximately 36 percent of the total number of seedlings were mechanically treated. If these seedlings had received a foliar application of herbicide instead, the amount of Razor Pro used would have increased approximately 400 ounces from the 700 ounces used to 1100 ounces. Another reason it was implemented was that it decreased the chance of a seedling being "missed" in any year. Several plots were over an acre in size and some had over a thousand seedlings. As the size of the plot increases and /or the number of seedlings increase, so does the chance of "missing" a seedling. The chances of finding all 4 seedlings in a plot that is 100 square feet in size are very high while finding all 500 seedlings in a plot that is an acre in size is very low. Assuming that during every visit that 80 percent of the seedlings are detected and treated (either mechanical or herbicided) and the plots were only visited once a year, 20 percent of the existing seedlings would be missed and be alive at the end of the year. If the plots are visited three times a year and 80 percent of the seedlings are detected each treatment round, only 1 percent of the existing seedlings would be alive at the end of the year. However, this example does not take into account seedlings that germinated during the year.

From 2007 to 2008, 3148 tree of heaven received a hack and squirt application of Garlon 3A. Approximately seven percent (228 trees) were still alive the following year and were re-treated. Most of the failures were caused by improper technique during the hack and squirt application. Due to competing vegetation such as vines and/or terrain features, the hatchet "hacks" were spaced too far apart or did not go completely around the tree. It was discovered during the first herbicide treatment round of 2008, after looking at the 2007 treated trees, that 1 ml. of Garlon 3A in properly spaced "hacks" is more effective than 2 ml. of Garlon 3A in half the number of "hacks". Learning from this mistake made in 2007, only two of the trees treated in 2008 had to be re-treated in 2009. Overall, there were only a handful of tree of heaven that were properly treated that had to be re-treated during a latter treatment.

As previously stated, removal of overstory and mid-story tree of heaven will allow more sunlight to reach the forest floor. Coupled with the fact that tree of heaven seedlings numbers have been reduced, this will stimulate the growth of other understory vegetation. Unfortunately, some of this additional growth may be other invasive species. For the most part, there has not been a noticeable increase in the amount of invasive species at most of the site. However, there has been increases in multiflora rose (*Rosa multiflora*) and Japanese honeysuckle (*Lonicera japonica)* in a few of the plots as well as an increase in Japanese knotweed (*Fallopia japonica*) in a few other plots. Removal of the overstory and mid-story tree of heaven has allowed more room for native vegetation in these areas to grow. Crown expansion and accelerated DBH growth should occur on this native vegetation.

CONCLUSION

Based on the amount and the size of some of the individual trees that existed at the start of the project in 2007, tree of heaven has been at FRHI for quite a while. This tree of heaven control project has significantly reduced the amount at FRHI, eliminated it from several areas and nearly eradicated it from the mid-story and overstory. The amount of herbicide used and the time spent conducting treatments have both been significantly reduced from the first year of the project. The diligent efforts and the hard work of all those involved on the project are now being seen.

There is a direct relationship between the size of the infestation and the length it takes to control. Based on individual plot data, smaller tree of heaven infestations can be controlled and in some cases can be eliminated in a year or two. Larger infestations will take additional years to control.

It is anticipated that there will be a very significant reduction in number of tree of heaven at FRHI in 2010. The anticipated low level warrants only one round of treatment. Therefore, it is recommended that only a single round of herbicide treatments be conducted in 2010. It is estimated that less than 10 ounces of Garlon 3A and 60 ounces of Razor Pro will be used and that the treatments will take less than 50 hours to complete.

APPENDIX A

Individual Plot Data

Table 1 – Number of TOH treated in 2007, 2008 and 2009 by size class for each plot established in 2007.

Plot #	Year	DBH									Total
		Seedlings (≤1″)	2″	4″	6″	8″	10″	12″	14″	≥16″	
1	2007	39	3	3	4	2	2	1	0	0	54
1	2008	126	0	0	0	0	0	0	0	0	126
1	2009	84	0	0	0	0	0	0	0	0	84
2	2007	26	3	1	3	0	0	0	0	0	33
2	2008	125	0	0	0	0	0	0	0	0	125
2	2009	20	0	0	0	0	0	0	0	0	20
3	2007	94	1	3	4	5	2	0	0	0	109
3	2008	106	0	0	0	0	0	0	0	0	106
3	2009	41	0	0	0	0	0	0	0	0	41
4	2007	58	1	0	1	1	0	0	0	0	61
4	2008	196	0	0	0	0	0	0	0	0	196
4	2009	10	0	0	0	0	0	0	0	0	10
5	2007	25	0	1	3	2	0	0	0	0	31
5	2008	41	0	0	1	0	0	0	0	0	42
5	2009	5	0	0	0	0	0	0	0	0	5
6	2007	0	0	0	0	0	0	0	1	0	1
6	2008	19	0	0	0	0	0	0	1	0	20
6	2009	0	0	0	0	0	0	0	0	0	0
7	2007	2	1	1	0	0	0	0	0	0	4
7	2008	3	0	0	0	0	0	0	0	0	3
7	2009	0	0	0	0	0	0	0	0	0	0
8	2007	94	2	0	0	1	0	1	0	0	98
8	2008	29	0	0	0	0	0	0	0	0	29
8	2009	0	0	0	0	0	0	0	0	0	0
9	2007	28	0	0	0	1	0	0	0	0	29
9	2008	1	0	0	0	0	0	0	0	0	1
9	2009	0	0	0	0	0	0	0	0	0	0
10	2007	580	8	18	28	34	17	4	1	2	692
10	2008	1658	1	0	1	0	0	0	0	0	1660
10	2009	335	0	0	0	0	0	0	0	0	335
11	2007	885	8	10	11	11	7	2	0	4	938
11	2008	2124	0	1	0	1	1	0	0	1	2128
11	2009	230	1	0	0	1	0	0	0	0	232
12	2007	8	0	1	0	3	1	0	0	0	13
12	2008	200	0	0	0	2	0	0	0	0	202
12	2009	93	0	0	0	0	0	0	0	0	93
13	2007	4	3	3	0	1	1	0	0	0	12
13	2008	73	0	1	0	2	0	0	0	0	76
13	2009	15	1	0	0	0	0	0	0	0	16
14	2007	21	1	1	0	5	0	0	0	0	28
14	2008	194	0	0	0	1	0	0	0	0	195
14	2009	35	0	0	1	1	0	0	0	0	37

Table 1 (continued) – Number of TOH treated in 2007, 2008 and 2009 by size class for each plot established in 2007.

Plot #	Year	DBH									Total
		Seedlings (≤1″)	2″	4″	6″	8″	10″	12″	14″	≥16″	
15	2007	792	32	12	2	7	2	2	1	1	851
15	2008	2277	1	1	0	0	0	0	0	0	2279
15	2009	414	1	1	0	1	0	0	0	0	417
16	2007	273	19	14	3	0	1	0	0	0	310
16	2008	201	4	2	0	0	0	0	0	0	207
16	2009	94	0	0	0	0	0	0	0	0	94
17	2007	0	4	2	1	0	0	0	1	1	9
17	2008	135	1	0	0	0	0	0	0	0	136
17	2009	35	0	0	0	0	0	0	0	0	35
18	2007	35	14	17	5	2	0	1	0	2	76
18	2008	308	1	1	1	0	0	0	0	2	313
18	2009	40	0	0	0	0	0	1	0	0	41
19	2007	73	28	41	19	6	1	0	0	0	168
19	2008	323	4	5	3	0	0	0	0	0	335
19	2009	24	0	1	0	1	0	0	0	0	26
20	2007	27	1	0	0	1	0	0	0	0	29
20	2008	101	0	0	0	0	1	0	0	0	102
20	2009	28	1	0	0	0	0	0	0	0	29
21	2007	75	0	1	0	2	2	0	0	0	80
21	2008	101	0	0	0	0	1	0	0	0	102
21	2009	18	1	0	0	0	1	0	0	0	20
22	2007	117	4	2	2	2	0	0	1	0	128
22	2008	125	0	0	0	0	0	0	0	0	125
22	2009	108	0	0	0	0	0	0	0	0	108
23	2007	0	0	2	1	0	0	1	0	0	4
23	2008	36	0	0	0	0	0	0	0	0	36
23	2009	0	0	0	0	0	0	0	0	0	0
24	2007	1021	6	4	5	4	2	0	0	0	1042
24	2008	671	1	0	1	0	0	0	0	0	673
24	2009	39	0	0	0	0	0	0	0	0	39
25	2007	1337	45	11	8	5	5	4	5	4	1424
25	2008	690	2	0	0	0	0	1	0	0	693
25	2009	59	4	0	0	0	0	0	2	0	65
26	2007	1042	14	3	0	1	0	0	2	2	1064
26	2008	1957	4	0	0	0	0	0	1	0	1962
26	2009	42	7	1	0	0	0	0	0	0	50
27	2007	2442	65	33	16	13	14	5	2	12	2602
27	2008	1286	8	2	1	0	0	0	1	1	1299
27	2009	142	5	0	0	0	0	0	0	0	147
28	2007	9	10	1	1	0	0	0	1	1	23
28	2008	13	1	2	5	0	0	0	0	0	21
28	2009	0	0	0	0	0	0	0	0	0	0

Table 1 (continued) – Number of TOH treated in 2007, 2008 and 2009 by size class for each plot established in 2007.

Plot #	Year	DBH									Total
		Seedlings (≤1″)	2″	4″	6″	8″	10″	12″	14″	≥16″	
29	2007	564	12	7	1	0	1	0	0	1	586
29	2008	361	8	5	2	0	1	0	0	0	377
29	2009	50	0	0	0	0	0	0	0	0	50
30	2007	134	1	6	2	1	1	0	0	0	145
30	2008	469	0	1	1	0	0	0	0	0	471
30	2009	53	0	0	0	0	0	0	0	0	53
31	2007	2	0	1	0	0	0	0	0	0	3
31	2008	0	0	0	0	0	0	0	0	0	0
31	2009	38	0	0	0	0	0	0	0	0	38
32	2007	21	0	0	1	3	0	0	0	0	25
32	2008	177	0	0	0	0	0	0	0	0	177
32	2009	18	1	0	0	0	0	0	0	0	19
33	2007	0	0	0	0	1	0	0	0	0	1
33	2008	12	0	0	0	1	0	0	0	0	13
33	2009	6	0	0	0	0	0	0	0	0	6
34	2007	315	15	7	6	3	1	0	1	0	348
34	2008	335	5	1	0	2	0	0	1	0	344
34	2009	118	3	1	0	1	0	0	1	1	125
35	2007	282	41	15	5	6	1	2	2	2	356
35	2008	485	11	8	6	5	1	0	0	0	516
35	2009	88	1	0	0	1	0	0	0	0	90
36	2007	3	3	3	0	0	1	0	0	0	10
36	2008	8	0	1	0	0	0	0	0	0	9
36	2009	0	0	0	0	0	0	0	0	0	0
37	2007	6	0	0	0	1	0	0	0	0	7
37	2008	4	0	0	0	0	0	0	0	0	4
37	2009	0	0	0	0	0	0	0	0	0	0
38	2007	117	5	3	2	0	0	0	0	0	127
38	2008	118	0	0	0	0	0	0	0	0	118
38	2009	12	0	0	1	0	0	0	0	0	13
39	2007	260	2	1	0	0	0	0	0	0	263
39	2008	62	0	0	0	0	0	0	0	0	62
39	2009	5	0	0	0	0	0	0	0	0	5
40	2007	283	4	4	1	2	0	0	0	0	294
40	2008	77	1	0	1	1	0	0	0	0	80
40	2009	6	0	0	0	0	0	0	0	0	6
41	2007	22	2	4	2	1	0	0	0	0	31
41	2008	70	0	0	1	2	0	0	0	0	73
41	2009	7	0	0	0	0	0	0	0	0	7
42	2007	45	3	1	0	1	0	0	0	0	50
42	2008	27	1	1	0	0	0	0	0	0	29
42	2009	2	0	0	0	0	0	0	0	0	2

Table 1 (continued) – Number of TOH treated in 2007, 2008 and 2009 by size class for each plot established in 2007.

Plot #	Year	DBH									Total
		Seedlings (≤1″)	2″	4″	6″	8″	10″	12″	14″	≥16″	
43	2007	186	2	4	2	1	0	0	0	0	195
43	2008	55	0	0	0	0	0	0	0	0	55
43	2009	2	0	0	0	0	0	0	0	0	2
44	2007	351	4	7	3	6	1	0	0	0	372
44	2008	761	2	5	3	5	1	0	0	0	777
44	2009	317	0	0	0	0	0	0	0	0	317
45	2007	548	11	13	12	5	4	2	2	1	598
45	2008	1336	1	2	6	3	0	1	1	0	1350
45	2009	307	1	2	0	0	1	0	0	0	311
46	2007	15	0	2	4	4	3	1	1	0	30
46	2008	174	0	1	3	3	3	1	0	0	185
46	2009	93	0	0	1	1	0	0	1	1	97
47	2007	1	1	1	0	0	0	0	0	0	3
47	2008	83	0	1	0	0	0	0	0	0	84
47	2009	7	0	0	1	0	0	0	0	0	8
48	2007	94	5	3	1	5	6	0	3	1	118
48	2008	634	3	0	2	2	1	0	3	0	645
48	2009	28	0	0	0	1	0	0	0	0	29
49	2007	1	2	6	0	0	0	0	0	0	9
49	2008	55	0	2	0	0	0	0	0	0	57
49	2009	3	0	0	0	0	0	0	0	0	3
50	2007	95	5	2	2	4	2	0	0	0	110
50	2008	342	2	2	0	1	1	1	0	0	349
50	2009	39	0	0	0	0	0	1	0	0	40
51	2007	635	21	4	1	0	0	1	1	3	666
51	2008	790	1	2	1	0	1	1	0	3	799
51	2009	228	2	0	0	1	0	1	0	0	232
52	2007	59	0	0	1	0	0	0	0	0	60
52	2008	4	0	0	0	0	0	0	0	0	4
52	2009	0	0	0	0	0	0	0	0	0	0
53	2007	862	14	6	5	7	1	3	2	1	901
53	2008	789	9	6	5	2	3	1	2	2	819
53	2009	321	3	0	0	0	0	0	1	0	325
54	2007	638	50	49	14	15	6	8	7	7	794
54	2008	697	16	9	10	9	9	4	6	6	766
54	2009	214	2	5	0	3	0	1	0	0	225
99	2007	3	2	0	0	2	0	0	0	0	7
99	2008	54	0	0	1	1	1	0	0	0	57
99	2009	0	0	0	0	0	0	0	0	0	0
98	2007	31	20	3	2	1	0	0	0	0	57
98	2008	103	4	3	1	2	0	1	0	0	114
98	2009	28	0	0	0	0	0	0	0	0	28

Table 1 (continued) – Number of TOH treated in 2007, 2008 and 2009 by size class for each plot established in 2007.

Plot #	Year	DBH									Total
		Seedlings (≤1″)	2″	4″	6″	8″	10″	12″	14″	≥16″	
97	2007	19	0	0	3	0	0	0	0	0	22
97	2008	72	0	0	1	0	0	0	0	0	73
97	2009	37	0	0	0	0	0	0	0	0	37
96	2007	410	38	14	8	10	4	0	2	2	488
96	2008	297	33	22	9	7	1	2	4	2	377
96	2009	122	8	2	2	2	1	0	0	0	137
95	2007	36	12	4	0	1	0	0	0	0	53
95	2008	18	0	0	0	0	0	0	0	0	18
95	2009	0	0	0	0	0	0	0	0	0	0
94	2007	5	0	0	0	1	0	0	0	0	6
94	2008	25	0	0	0	0	0	0	0	0	25
94	2009	1	0	0	0	0	0	0	0	0	1
93	2007	7	2	4	0	0	0	0	0	1	14
93	2008	40	0	0	1	0	0	1	0	1	43
93	2009	12	0	0	0	0	0	0	0	0	12
92	2007	0	0	1	0	0	0	0	0	0	1
92	2008	1	0	1	0	0	0	0	0	0	2
92	2009	0	0	0	0	0	0	0	0	0	0
A	2007	98	2	0	0	0	0	0	0	0	100
A	2008	97	1	0	0	0	0	0	0	0	98
A	2009	13	0	0	0	0	0	0	0	0	13
B	2007	46	1	0	0	0	0	0	0	0	47
B	2008	28	0	0	0	0	0	0	0	0	28
B	2009	0	0	0	0	0	0	0	0	0	0
C	2007	9	2	0	0	0	0	0	0	0	11
C	2008	0	0	0	0	0	0	0	0	0	0
C	2009	0	0	0	0	0	0	0	0	0	0
D	2007	76	0	0	0	0	0	0	0	0	76
D	2008	64	0	0	0	0	0	0	0	0	64
D	2009	3	0	0	0	0	0	0	0	0	3
E	2007	2212	18	4	3	7	2	1	0	0	2247
E	2008	1775	4	0	0	0	0	0	1	0	1780
E	2009	88	0	0	0	0	0	0	0	0	88
F	2007	801	15	1	4	1	2	4	0	1	829
F	2008	883	3	0	0	0	0	0	0	0	886
F	2009	55	0	0	0	0	0	0	1	0	56

Table 1 (continued) – Number of TOH treated in 2007, 2008 and 2009 by size class for each plot established in 2007.

Plot #	Year	DBH									Total
		Seedlings (≤1″)	2″	4″	6″	8″	10″	12″	14″	≥16″	
G	2007	435	14	1	1	0	0	0	1	1	453
G	2008	156	3	1	0	1	2	1	1	0	165
G	2009	78	0	0	0	1	0	0	0	0	79
H	2007	61	0	0	0	0	0	0	0	0	61
H	2008	16	0	0	0	0	0	0	0	0	16
H	2009	5	0	0	0	0	0	0	0	0	5
I	2007	1	0	0	0	0	0	0	0	0	1
I	2008	0	0	0	0	0	0	0	0	0	0
I	2009	0	0	0	0	0	0	0	0	0	0
J	2007	0	0	1	0	0	0	0	0	0	1
J	2008	0	0	0	0	0	0	0	0	0	0
J	2009	0	0	0	0	0	0	0	0	0	0
K	2007	451	58	2	5	6	0	2	2	2	528
K	2008	458	14	8	3	1	0	1	2	0	487
K	2009	57	4	2	0	0	0	0	0	0	63

Table 2 – Number of TOH treated in 2008 and 2009 by size class for each plot established in 2008.

Plot #	Year	DBH								Total
		Seedlings (≤1″)	2″	4″	6″	8″	10″	12″	14″	≥16″	
91	2008	166	23	13	7	1	1	0	0	1	212
91	2009	26	0	0	0	0	0	0	0	1	27
90	2008	1	0	2	1	1	2	2	2	2	13
90	2009	0	0	0	0	0	0	0	0	1	1
89	2008	337	3	0	3	1	5	2	1	3	355
89	2009	236	0	0	0	0	1	0	1	0	238
88	2008	139	28	18	3	1	0	0	0	0	189
88	2009	174	1	0	0	1	0	0	0	0	176
87	2008	378	6	6	0	0	1	0	1	1	393
87	2009	237	0	1	1	1	0	0	0	0	240
86	2008	24	1	1	1	0	0	0	0	0	27
86	2009	9	0	0	0	0	0	0	0	0	9
85	2008	43	0	0	2	0	0	0	0	1	46
85	2009	56	0	0	0	0	0	0	0	0	56
84	2008	5	0	0	0	0	0	1	0	0	6
84	2009	4	0	0	0	0	0	0	0	0	4
83	2008	32	4	2	2	1	2	1	0	0	44
83	2009	33	0	0	0	0	1	0	0	0	34
82	2008	0	0	0	1	2	2	0	0	0	5
82	2009	115	0	0	0	0	0	0	0	0	115
81	2008	49	0	2	2	3	1	0	1	0	58
81	2009	379	0	0	0	0	0	0	0	0	379
80	2008	3	0	0	0	0	1	0	0	0	4
80	2009	4	0	0	0	0	0	0	0	0	4
L	2008	134	17	0	1	0	2	0	0	0	154
L	2009	131	0	0	0	0	0	0	0	0	131
M	2008	3	1	0	1	0	0	0	0	0	5
M	2009	0	0	0	0	0	0	0	0	0	0

Table 3 – Number of TOH treated in 2009 by size class for each plot established in 2009.

Plot #	Year	DBH								Total
		Seedlings (≤1″)	2″	4″	6″	8″	10″	12″	14″	≥16″	
76	2009	0	6	2	0	0	0	0	0	0	8
77	2009	24	0	0	1	0	0	0	0	0	25
78	2009	0	0	0	0	1	0	0	0	0	1
79	2009	161	0	2	2	2	1	2	1	0	171

APPENDIX B

Pictures of the TOH control project

A portion of plot # 26 prior to treatment. The tree of heaven is marked with orange and yellow paint.

A pile of pulled tree of heaven seedlings.

Foliage on a tree of heaven 3 days after treatment with Garlon 3A

Foliage on a tree of heaven 7 days after treatment with Garlon 3A

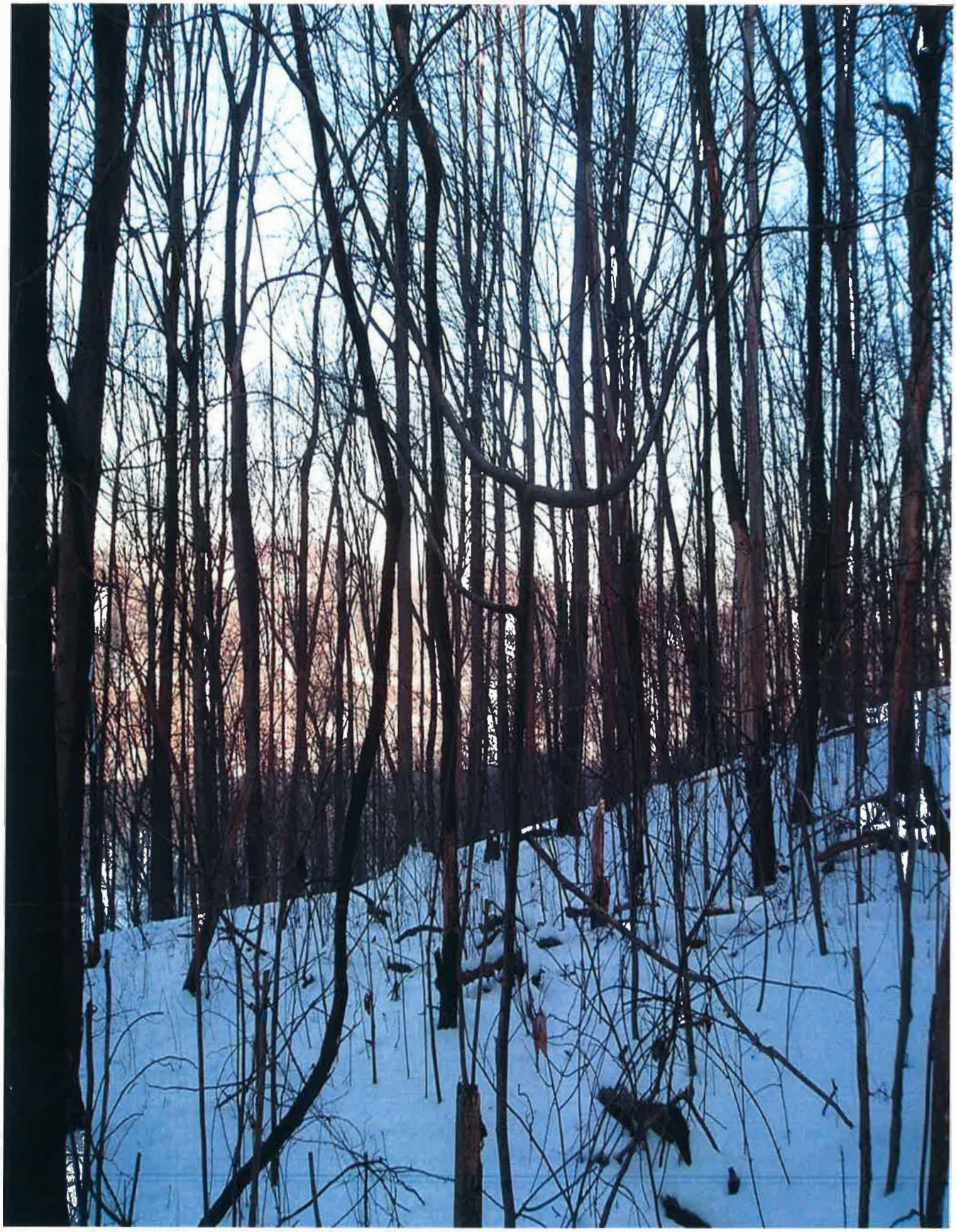
Foliage on tree of heaven 21 days after treatment with Garlon 3A.

Aerial view of plot #s 10, 11 and 12 twenty-one days after treatment with Garlon 3A. The declining trees are treated tree of heaven. The scattered trees with the yellow crowns (most are located in the middle of the photo) are treated trees.

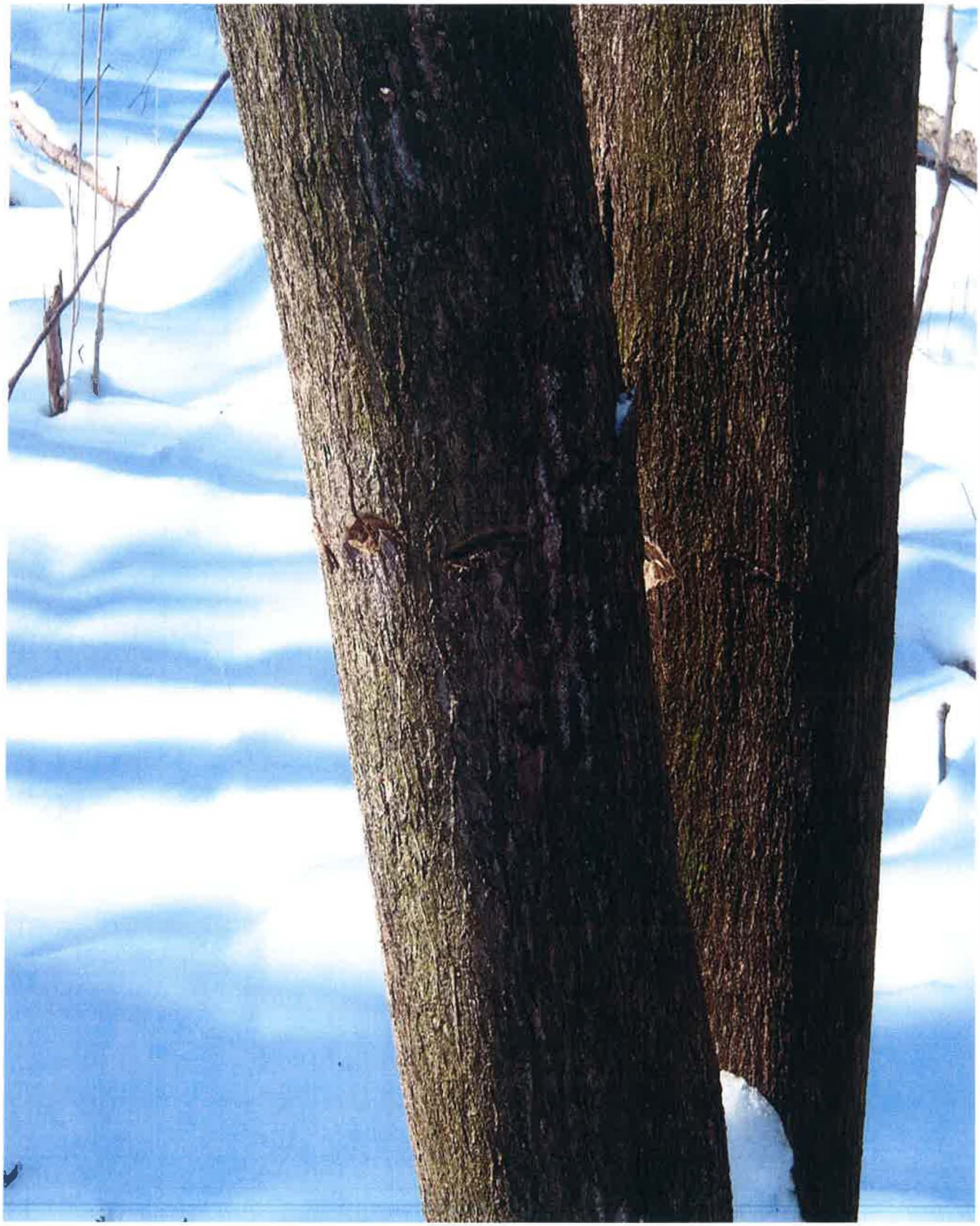
Two large tree of heaven 6 weeks after treatment with Garlon 3A (cover picture)

Two tree of heaven 9 months after treatment with Garlon 3A. The boles of these trees have already snapped off.

Several dead tree of heaven 9 months after treatment with Garlon 3A. The bark has already sloughed off most of the boles.



Same part of plot #26 as shown on page 24 but 2 ½ years after treatment.

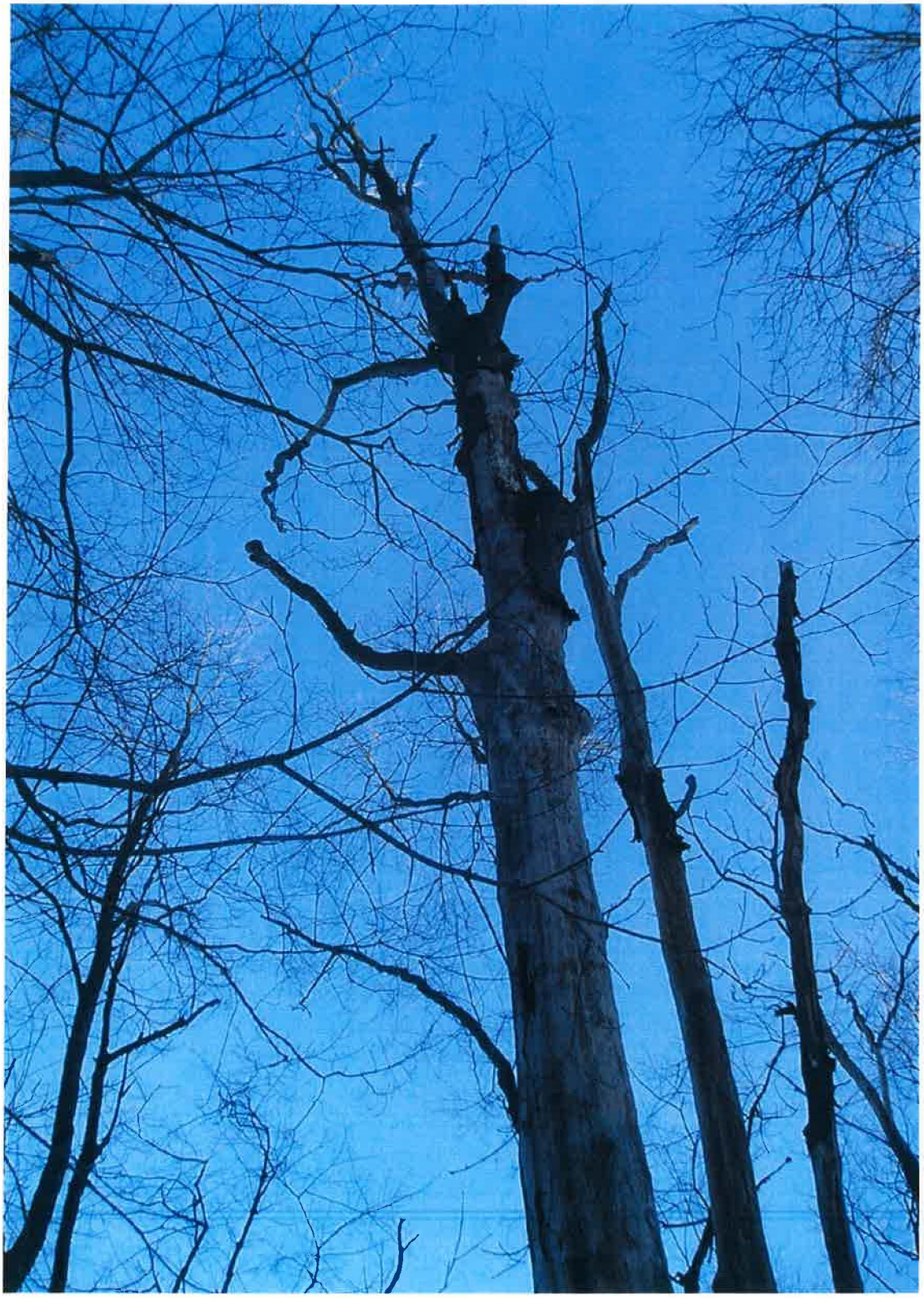


Properly spaced hatchet "hacks" on two tree of heaven.

Portion of plot number nineteen 2 ½ years after treatment.

Same trees shown on page 28 but 2 ½ years after treatment. This plot (plot # 1) has had an increase in multiflora rose and Japanese honeysuckle since treatment.

Tree of heaven that was treated twice (two rows of hatchet "hacks" are present). Large poison ivy vine made difficult to properly space "hacks".



A few dead tree of heaven 2 ½ years after treatment. The large one in the center of picture was 22″ DBH.